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Diffusion-limited aggregation at multiple centers: Model of dendrite growth at ion beam synthesis of magnetic films in external field

N.A. Balakirev [a,*], G.G. Gumarov [b,c], V.A. Zhikharev [a], V.Y. Petukhov [b,c]

[a] *Kazan State Technological University, 68 Karl Marx Street, Kazan 420015, Republic of Tatarstan, Russian Federation*
[b] *Zavoisky Physical-Technical Institute of the Kazan Scientific Center of the Russian Academy of Science, Kazan, Russia*
[c] *Kazan Federal University, 18 Kremlyovskaya Street, Kazan 420008, Republic of Tatarstan, Russian Federation*

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ABSTRACT

Computer simulations are used to generate two-dimensional dendrites from atoms carrying magnetic moment being parallel to the external magnetic field. The numerical model is based on the model of diffusion-limited aggregation at multiple centers. The magnetic dipole–dipole interaction between diffusing implanted atoms and growing ferromagnetic dendrites is taken into account. It is shown that magnetically induced anisotropy of grown dendrites follows to elongation of them in external field direction. The process of growth of these dendrites is analyzed by measuring mean relative elongation versus number of deposited particles within the grid.

1. Introduction

The formation of clusters or dendrites of new phase as a result of aggregation of diffusing particles is an initial stage of the variety of technological processes. Although many mechanisms can be involved in these processes, the theoretical consideration of main features of dendrite structure is usually based on simple models taking into account only the effects of thermal diffusion, one of them being the model of diffusion-limited aggregation (DLA) [1]. Despite a very simple algorithm, this model allows to trace the details of the dendrite growth. Different variations of DLA model are used depending on the geometry of the new phase growth. The diffusion limited deposition (DLD) is a version of DLA for description of the growth of dendrites on fibers and surfaces [2,3]. In DLD model the particles diffuse over d-dimensional space, but attach to a (d-1)-dimensional dendrite. Such a situation takes place at the electrodeposition from liquid or gaseous phases on solid substrates. Recently [4], the DLA model was used to simulate the formation of dendrite structure of ferromagnetic silicide Fe_3Si at high dose Fe-ion implantation into silicon target. In this case, the DLA model with many dendrite growth centers [5] has been considered. The morphology of dendrite grown in the presence of neighbors may be quite different from that obtained for isolated dendrite. Moreover the magnetic (dipole–dipole) interaction between diffusing implanted atoms and growing ferromagnetic dendrites should be considered. The roll of magnetic interactions in the DLD model of dendrite growth were considered in [6]. The importance of such interactions in transformation of the shape of the precipitate during Ostwald ripening processes was shown in [7].

In this paper DLA model of dendrite structure formation by high dose ion implantation (ion beam synthesis (IBS)) is developed. At relatively low doses of implantation the single-center DLA model can be used to describe the isolated dendrites observed. At high doses (IBS conditions) it is necessary to solve the problem of diffusion-limited aggregation at multiple centers (multicenter DLA problem), taking into account the magnetic interactions in order to simulate the growth of dendrites. In [4] the ion beam synthesis of silicides was performed in the presence of external magnetic field $\vec{B}_c$, which is also considered in the model developed.

2. Theory Multicenter DLA model at ion beam implantation

Atoms implanted into the solid are localized within a thin layer near the target surface. Due to radiation damages the diffusion of implants in plane of the layer is more intense than that out of plain the layer. This results in the formation of a thin film consisting of clusters of new phase. As a model approximation, the ion implantation can be considered as the addition of particles one at a time to sites of a two-dimensional squared grid. Then, according to DLA approach, the particle motion is described as a random walking over the grid. The actual depth distribution of implants and three-dimensional diffusion of the particles will be discussed in our further works. The added particle moves until it contacts the growing aggregate.

* Corresponding author. Tel.: +7 843 231 41 08; fax: +7 843 238 56 94.
E-mail addresses: balakirevnikita2009@gmail.com, balakirevnikita2009@yandex.ru (N.A. Balakirev).

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